Design4Health Bootcamp: A design thinking approach to improve the 21st century skills of health, engineering and design students

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***Abstract*— Global industries are acknowledging that professions as we know them will not require the same skills as they did in the 20th Century. Therefore how can universities prepare students for challenges that have not been fully identified? This paper will present the Design4Health Bootcamp, an initiative that intends to close the so-called "21st century skills gap". We present its course curriculum, quantitative and qualitative evaluation and conclude with a set of principles that support the implementation of such initiatives.**

Keywords—Design Thinking, Health Challenges, 21st Century Skills, Education

I. INTRODUCTION

The fourth industrial revolution is prompting a fundamental transformation in the way we work, live and relate to each other [1]. Our economy is adapting as we shift from the industrial age to the information age due to the combined impact of technology and globalization that in turn is affecting changes in job and skills requirements that will shape the future of work and society [2]. In fact, industries are already acknowledging that professions as we know them are changing, doctors, engineers, designer and many other disciplines will not require the same skills as they did in the 20th Century. In line with this transition, skills and knowledge gaps are already being identified in current graduate employees that are lacking in communication, critical thinking, problem solving, professionalism, collaboration and leadership skills to name a few, this deficit is being referred to as the "21st Century skills gap" [3].

It is therefore critical that education institutions commit to reform in order to adapt to the changing needs of the industries and professions that will emerge and evolve during this period. Graduates should be equipped with the mind and skillset to be "creative creators" who are collaborative, confident, imaginative and can adapt to future job requirements [1], [2].

The challenge of how education can adapt to meet these unmet needs can be sought by first looking back before moving forward. In the 1960s, Education philosopher, Paulo Freire brought to light the need to challenge "traditional" approaches to education in his seminal work *Pedagogy of the Oppressed* [4]. Freire explained that the traditional teacher-centered model of education in which the educator is the purveyor of knowledge and the student is an "empty receptacle" that requires filling with the educator's knowledge is not an effective approach to education as we leave the industrial age [4]. Some 40 years later, the same ideology was being echoed in Ken Robinson's 2008 Royal Society of Arts (RSA) speech entitled *Changing education paradigms*, further adding credence to the work of Freire while also reminding us little has changed over time. Robinson argued that learners need to be equipped with skills to focus and utilize information to its fullest, to think creatively and divergently [5].

As opposite to the traditional teacher-centered approach, education must adopt a more learner-centered approach that is informed by the Science of how we learn and equip learner with the skills and knowledge required to succeed in the information age [6], [7]. However, the mission is not easy, given that Educators often teach how they were taught, reverting to the teacher being in control of the class and talking, while the learners listen and take notes, "The problem is they're trying to meet the future by doing what they did in the past" [5].

Inevitably industries arrived at the same observation and worked on multiple initiatives to communicate their needs to the educational system. The most prominent work is certainly the 21st Century Skills (ATC21S) project, created by technology giants Cisco, Intel and Microsoft in 2009 [8]. The ATC21S describes educational standards to support learning 21st Century skills and importantly guiding principles to assess those skills. The ten skills that have been identified and grouped into four categories are, Ways of Thinking; 1. Creativity and innovation, 2. Critical thinking, problem solving, decision making, 3. Learning to learn, Metacognition; Ways of Working, 4. Communication, 5. Collaboration (teamwork); Tools for Working, 6. Information literacy, 7. ICT literacy. Living in the World; 8. Citizenship – local and global, 9. Life and career, 10. Personal & social responsibility – including cultural awareness and competence.

Though many disciplines are behind when it comes the 21st century skills, it can be argued that Health Professions Education (HPE) suffers even more than most. This can be attributed to a change resistance culture, Medical schools' deep-seated values, traditions, and challenging accreditation process can add to the resistance to develop curriculum that moves away from the information retention model to a more learner-centered approach [7], [9].

In this paper we present the Design4Health Bootcamp, an initiative that intends to close the so-called "21st century skills gap". Building on Design Thinking, we put forward a structured curriculum that we further evaluated by means of a questionnaire and interviews. We then discuss the results and suggest three core principles that contributed to the success of the bootcamp.

II. Prior Literature

While work has been done on the identification of the 21st century skills that can be developed in learners of today for jobs of tomorrow, the real challenge is how to teach and foster this skillset in a learner-centered manner. As the aim is to move away from a traditional approach to education, learner-centered peadagogies should be considered. Experiential learning is an example of one such approach that supports the development of skills and knowledge through experiences, often in a non-traditional educational setting.

Building on original pioneers such as Dewey and his concept of "learning by doing" [10], David Kolb has brought to light the potential of experiential learning in more recent times through the development of his cyclical model (Fig. 1) that illustrates how learners draw upon experience (feeling) that can be reflected upon (watching) to conceptualize a theory or model (thinking) before implementing said theory or model (doing).

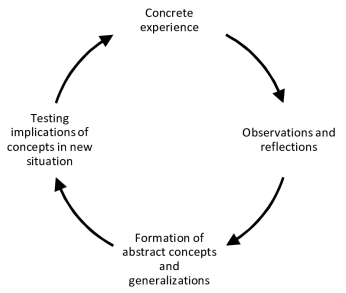

Fig. 1. Kolb's cyclical model

Experiential learning can be taught with educational techniques such as problem-based learning, action learning or team-based learning and can support the development of lifelong learning approaches [11].

Problem-based learning or (PBL) has been adopted in many Health professions curricula to encourage a shift towards a learner-centered instructional approach. PBL puts learners into small groups to work both collectively and individually in order to identify and learn new information that can be used to solve a problem or scenario [12]. This approach encourages learners to develop skills around self-study, reflection and collaboration with peers to access, consolidate and understand information, refine and accumulated information to construct a response [13]. This approach also works in transitioning the role of the educator to a facilitation role, responsible for encouraging strategies of thinking and questioning rather than offering information or answers [12].

While PBL is said to offer a deeper learning experience that touches on developing some of the identified 21st century skills, it is still highly structured and generally classroom based, therefore does not address many skills around creativity, divergent thinking and innovation [12].

An alternate approach that has been gaining a lot of interest in Health Professions Education is Design Thinking [14]. Design Thinking is a practical approach to experiential learning that offers an iterative process to complex problem solving while building creative confidence, encouraging critical thinking through and partaking in collaborative activities that can in turn lead to creative and innovative outcomes [15]. Design Thinking combines convergent and divergent thinking, visualization techniques, multidisciplinary teams and a structured approach to human-centered design that provides a much more comprehensive approach to the development of 21st century skills [16], [17]. This human-centered approach to overcoming challenges has direct and relatable advantages to future health professions, by encouraging and providing strategies to empathize with the person or patient at the center of a healthcare issue, while also encouraging the support and input from other professional colleagues to provide alternative insights when searching for appropriate solutions [18]. Design Thinking is seen by clinicians as a way to "acquire essential transferable life-long learning skills in dealing with uncertainty and collaborative team working" [17].

III. Teaching the 21st century skills - Design4Health Bootcamp

In order to help students to develop their 21st century skills we developed the so-called Design4Health Bootcamp. The latter was a collaborative initiative of three universities located in the United Arab Emirates. Each university was represented by a particular college, providing faculty and students from the professions of medicine, design, computer science and engineering. The bootcamp's main focuses were innovation and multidisciplinary collaboration around the concept of healthcare improvement. Rather than working on fictional challenges, real world challenges were sought through our collaborations with local hospitals. They provided existing health challenges that impacted both medical staff and patients. In total 17 students were dispatched in three groups, each made up of two medical students, two computer engineers and one designer (expect for one group that only had one engineer). Each team worked independently on one challenge. Though three hospitals participated, two suggested the same challenge – i.e., decreasing the number of no-shows in outpatient clinics, while the other asked a team to investigate how to increase satisfaction feedback from outpatients.

	Understand and Empathize	Define	Ideate	Prototype I	Test	Prototype II
Duration	**Full day**	**Full day**	**Half-day**	**Full day**	**Half-day**	**Half-day**
Teaching capsules	• **Design Thinking** • **Patient-centered design** • **Challenge presentations by hospitals** • **Tools for observation and user research**	• Findings analysis • Define value proposition • Define p**roblem statement**	• **Idea generation in the design thinking process** • **Ideation tools** • **Ideation and brainstorming rules and objectives**	• **What and why prototyping and idea visualization**	• **How to test a prototype** • **Test scenarios** • **Documenting and building on feedback**	• **Presentation guidelines**
Techniques and tools	• **WH+H questions** • **Empathy map**	• **Personas** • **Patient journey map** • **Value Proposition Canvas (left part)**	• **Brainstorming** • **635 Brainwriting** • **Mindmapping** • **Idea Sheets** • **Impact/effort matrix**	• **Prototyping: Fidelity matrix** • **Access to Fabrication Lab (FabLab)**	• **A/B testing** • **Role play**	
Experential-Learning	• **Marshmallow challenge** • **Observations in hospitals** • **Interviews with medical staff** • **Survey patients**	• **Customer description with personas** • **Experience description with patient journey map** • **Customer pains and gains definition**	• **Brainstorm session I** • **Jigsaw feedback** • **Brainstorm session II** • **635 Brainwriting** • **Idea selection**	• **Expert feedback on selected ideas** • **Prototyping session**	• **Test scenario creation** • **Test with medical staff in hospitals**	• **Test debriefing** • **Prototype refinements** • **Final presentations**
Outcomes	• **Interview transcript** • **Empathy map**	• **Several personas** • **Multiple patient journey maps** • **Problem statement**	• **Multiple ideas, from blue-sky to easily implementable** • **High-impact and low effort idea** • **High-impact and high-effort idea**	• **Patient journey maps** • **Wireframes** • **Physical prototypes**	• **Test documentation**	• **Final prototypes** • **Presentations**

Fig. 2. Design4Health Bootcamp - Course curriculum

Our course curricula built upon a learner-centered approach that encourages students (individually and within their team) to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a problem [19]. To do so, we leveraged an experiential learning approach by equipping students with different tools, techniques or approaches that they could instantiate (experience) in their challenge [20]. Introductory content was designed as a 10-20-minute theory capsule, followed directly by an application session of at least 30 minutes, giving the students time to experiment. From a content perspective, our curricula built upon the Design Thinking process, inspired by existing work from the Hasso Plattner Institute of Design [21]. We chose to implement the Double Diamond of the Design Council that visually supports the concept of convergent and divergent thinking [22]. Students focused on one Design Thinking step per day while iterating two times between the prototyping and testing steps. To keep the level of intensity high, we spanned our course curricula over five full days (Fig. 2). The week concluded with team presentations in front of experts in the fields of medicine, design and engineering as well as representatives from the participating hospitals.

IV. Method

The usefulness and impact of our curricula were evaluated by means of a questionnaire built upon ATC21S 21st Century Skills' four dimensions – i.e., ways of thinking, tools for working, ways of working and living in the world [23]. Each dimension consisted of six to nine questions that the participants rated using a 5-point Likert scale (i.e., 1: strongly disagree to 5: strongly agree). The questionnaire was sent electronically to the 17 participants at the end of the week. Students' seniority varied quite significantly across the three disciplines given the age of the three institutions: medical students from completed year 1 to completed year 3, engineering students from completed year 2 to postgraduates and design students had completed year 1. Prior to the bootcamp, experience with Design Thinking also differed: medical students had applied it one time, most of the engineering students had known it but they had not used it, while design students had used it multiple times. Due to a dedicated time for filling the questionnaire, the response rate was 100%. Data was analyzed using descriptive statistics with Microsoft Excel. Detailed results are presented in the Appendix.

V. Analysis and Findings

Results show that across the four 21st century skill's dimensions, the bootcamp was the most helpful for developing new *ways of thinking* (a=4.19). In particular, it helped students have a positive appreciation of learning, improve their adaptability and flexibility, and support their creativity. On the contrary, the bootcamp did not noticeably support students in implementing innovations. Though the participants were able to show their prototypes and ask for feedback, they did not have the chance to implement the solutions. The area that the students rated the highest relates to the openness of new ideas, information and tools (b2=4.53), which is part of the *tools for working*'s dimension. As described in the course curricula (Fig. 2), many techniques and tools were introduced followed by application time, which allowed students to choose what suited their needs best We argue that this flexibility differs from traditional classes that require students to implement very specific concepts, sometimes at the expense of their relevance. The course was

also shown to have a positive impact in improving *ways of working*. In particular, the participants strongly agreed that it improved their open minded and preparedness to listen (c3=4.43) and their ability to work more effectively in diverse teams (c5=4.34). Medical students in particular found collaborating intensely with engineering and design students to be very beneficial, according to their feedback. As oppose to both engineering and design students who worked on health-related projects as part of their programs, medical students focused on their field only. Hence, designing prototypes was something very new to them.

On the other hand, the results show that the bootcamp did not support students in improving their competency in writing and oral language (c1=3.47). This result is surprising given that students were communicating with hospitals and clinics two times and then presenting their outcomes in front of 20+ people on two occasions. When it comes to better prioritizing, planning and managing projects, student average reached c6=3.94. With little surprised, the dimension *living in the world* was the least impacted by the bootcamp with an average of 3.88. A possible explanation is the low scores of statements such as "d3...respect the privacy of others", and "d1..improve my awareness and understanding of rights and responsibilities as a global citizen", which don't seem to have a direct connection with the experience of the students during this workshop. However, it is surprising that the students rated somewhat low the ability to adapt to change 3.87 (d6). At various occasions they had to come up with new ideas or prototypes after talking to stakeholders. Looking at the raw data, it is unclear whether the students did not entirely understand the questions or felt uncomfortable answering them – e.g., five students chose to rate all the questions with a 4.

VI. Discussion

Looking at the evaluation, we argue that three core principles contributed to the success of our initiative. First is the multidisciplinary selection of participants. Each team consisted of students from medicine, engineering and design from three different universities with experience ranging from first year to postgraduate. While initially students tried to split the work according to their specialties, they were encouraged not to do so in order to gain more authentic insights. Therefore, we stressed the importance for the designers and engineers to go to the hospitals and talk to the medical staff to increase their understanding and empathy towards the people facing the challenge. Given that students came from different schools of thoughts, we often observed some engaged discussions that required compromises to be taken. The most interesting debates was in their approach: medical and engineering students are rather used to linear, systematic approaches relying on strong evidence supporting the move from step 1 to step 2. Oppositely, design students work with short iterations along with some trial and error, similar to the Design Thinking approach that we adhered to throughout course. These different mindsets were perceived very positively by the students with quotes such as: [We particularly enjoyed] "the diverse background of students and different perspectives and experiences they brought to the team", "the interaction between all the different disciplines", "interacting with different people and having an intellectual sharing of ideas".

The second core principle is a structured curricula and approach towards Design Thinking. Though similar bootcamps and hackathons have taken place in the UAE and beyond (e.g., ElsevierHack [24]), participants usually receive little guidance. Based on our observations (e.g., the authors have often served as mentors, facilitators and judges) participants therefore start prototyping very early before realizing that their prototype does not match the identified needs. With this in mind we took an alternative approach and developed a curricula structured upon the five main steps of Design Thinking [21] that we taught by means of theorical capsules and experimental learning [20].

The third and final core principle we followed was the implication of hospitals and clinics throughout the bootcamp. The fact that students worked on real challenges, presented by the stakeholders directly is key to increase the understanding of the challenge and to build empathy. Students also had the chance to observe and interview medical staff as well as present their early prototypes to gather feedback. In addition, faculty members also provided feedback and guided the students. The benefits of working on real challenges was received in the feedback: [It was a good experience] "communicating directly with the hospital staff and getting an inside view of their process and mindset".

Interestingly, and comparable to similar experiences conducted by the authors in other contexts, there seems to be an excessive focus by students on designing mobile-phone applications or "apps". One possible area for future development of the workshop could be to stimulate other types of solutions and explicitly discourage the development of apps, promoting solutions as design of systems, services and user experiences could provide more beneficial thinking strategies and solutions. This aligns with research that discusses the proliferation of new "health apps" [25] and questions the efficacy and usage or long-term adoption of these.

Another consideration for future workshops is the lack of financial viability, or even the lack of implementation of solutions. While the main aim of this type of projects is educational, it is desirable to try to extend its impact. For example, a possible way forward can be to include students from a business school in a future iteration.

VII. Conclusion

In this paper we describe the Design4Health Bootcamp, an initiative that intends to decrease the so-called "21st century skills gap" [3]. Our research puts forwards three main contributions: 1) A structured curriculum built upon Design Thinking that universities and industries can use to facilitate the implementation of similar initiatives. 2) An evaluation of the efficiency of Design Thinking on the 21st century skills. 3) Principles to maximize the success human-centered approaches to address health challenges.

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APPENDIX

a) Ways of Thinking. The bootcamp helped me to...	**AVG**	**STD**
a1...think more creatively	4.34	0.62
a2...work creatively with others	4.27	0.46
a3...implement innovations	3.93	0.89
a4...reason effectively and evaluate evidence	4.13	0.52
a5...solve problems	4.20	0.56
a5...articulate findings	4.07	0.70
a6...improve my self-motivation	4	0.65
a7...have a positive appreciation of learning	4.47	0.52
a8...improve my adaptability and flexibility	4.27	0.46
Total	**4.19**	**0.6**

b) Tools for working. The bootcamp helped me to…	**AVG**	**STD**
b1...improve my ability to access and evaluate information	3.93	0.88
b2...improve my use and management of information	4	0.53
b3...apply technology effectively	4.13	0.64
b4...be more open to new ideas, information, tools, and ways of thinking	4.53	0.52
b5...use ICT more accurately, creatively, ethically, and legally	3.53	0.92
b6...be more aware of cultural and social differences	4.33	0.62
b7...apply technology more appropriately and effectively	4.33	0.49
Total	**4.11**	**0.66**

c) Ways of working. The bootcamp helped me to…	**AVG**	**STD**
c1...improve my competency in written and oral language	3.47	1.06
c2...improve my open minded and preparedness to listen	4.43	0.65
c3...improve my sensitivity to cultural differences when communicating	4.27	0.70
c4...interact more effectively with others	4.2	0.56
c5...work more effectively in diverse teams	4.34	0.62

c6...better prioritize, plan, and manage projects	3.94	0.70
Total	**4.10**	**0.72**

d) Living in the world. The bootcamp helped me to…	**AVG**	**STD**
d1..improve my awareness and understanding of rights and responsibilities as a global citizen	3.8	0.41
d2...improve my preparedness to participate in community activities	4	0
d3...respect the privacy of others	3.73	0.46
d4...improve my ability to communicate constructively in different social situations	4	0
d5...better understand different viewpoints and perspectives	4	0
d6...improve my ability to adapt to change	3.87	0.52
d7...improve my ability to manage goals and time	3.8	0.41
d8...improve my ability to be a self-directed learner	3.74	0.59
d9...improve my ability to interact effectively with others	4	0
Total	**3.88**	**0.27**

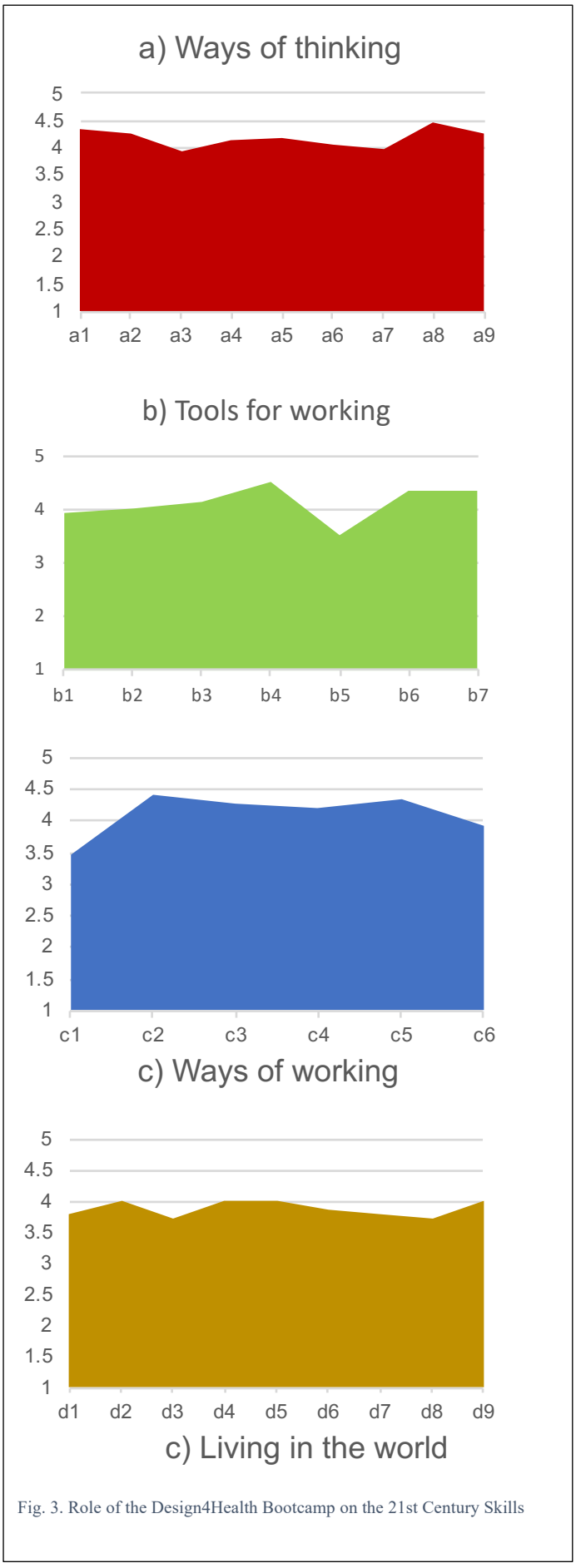

Fig. 3. Role of the Design4Health Bootcamp on the 21st Century Skills